METHOD OF DYNAMIC TRANSMIT SCHEDULING USING CHANNEL QUALITY FEEDBACK

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Field of the Invention

The present invention is related in general to communication systems, and, more particularly, to an improved method and system for dynamic scheduling via channel quality feedback.

Background of the Invention

Standards bodies such as the International Standards Organization (ISO) have adopted a layered approach for the reference model of a communication subsystem. The complete communication subsystem is broken down into a number of layers, each of which performs a well-defined function in the context of the overall communication subsystem. It operates according to a defined protocol by exchanging messages, both user data and additional control information, with a corresponding peer layer in a remote system. Each layer has a well-defined interface between itself and the layer immediately above and below. Consequently, the implementation of a particular protocol layer is independent of all other layers. The function of each layer is specified formally as a protocol that defines the set of rules and conventions used by the layer to communicate with a similar peer layer in another (remote) system. Each layer provides a defined set of services to the layer immediately above. It also uses the services provided by the layer immediately below it to transport the message units associated with the protocol to the remote peer layer.

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Communication systems, such as Code Division Multiple Access (CDMA) systems, communicate messages between infrastructure equipment and subscriber or mobile units. As used herein, a forward or downlink channel refers to data generated by cellular infrastructure equipment and transmitted for reception by a mobile communication unit, and a reverse or uplink channel refers to data generated by a mobile communication unit, such as a mobile cellular phone and transmitted for reception by the cellular infrastructure equipment, spefically a base station.

At the most basic level, cdma2000 provides protocols and services that correspond to the bottom two layers of the ISO/OSI Reference Model (i.e., Layer 1 -- the Physical Layer, and Layer 2 -- the Link Layer) according to the general structure specified by the ITU for IMT-2000 systems. In cdma2000, a generalized multi-media service model is supported. This allows a combination of voice, packet data, and circuit data services to be operating concurrently (within the limitations of the air interface system capacity). Cdma2000 also includes a Quality of Service (QOS) control mechanism to balance the varying QOS requirements of multiple concurrent services.

One problem associated with the combination of voice, packet data, and circuit data services operating concurrently is the ability to maintain a high data rate connection at a required fixed error rate over a channel of varying quality. In addition, maximizing system capacity when high data rate channels are active presents another problem. Consequently, a need exists for a method and system for dynamic rate switching and scheduling control, wherein data rates for high data rate channels are automatically shifted up or down based on a channel quality feedback.

Brief Description of the Drawings

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objects, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

FIG. 1 depicts a communication system in accordance with the method and system of the present invention;

FIG. 2 illustrates a block diagram of a communication system layer structure in accordance with the method and system of the present invention;

FIG. 3 illustrates a fading profile of a typical wireless communication channel;

FIG 4. Scheduling based on C/I measurements provided by each remote unit A and B.

FIG 5. Shows that the forward dedicated control channel (DCH) voltage gain levels of remote unit A and B can be used to determine scheduling priority on the common channel.

FIG 6. Shows that the accumulation of power control commands (also called the closed loop gain adjustment (CGA)) of the forward dedicated control channel (DCH) of remote unit A and B.

FIG. 7 illustrates the nature of the channel statistics and important channel metrics;

FIG. 8 illustrates an example of scheduling a plurality of users based on the channel statistics in accordance with the method and system of the present invention;

FIG. 9 illustrates a functional flow diagram depicting the process of base transceiver station transmit scheduling for a plurality of users in accordance with the method and system of the present invention;

Detailed Description of the Invention

FIG. 1 depicts a communication system **100** in accordance with the preferred embodiment of the present invention. System **100** includes a mobile station **102**, a first base transceiver station **104**, a second base transceiver station **103**, and a Centralized Base Station Controller (CBSC) **105**. CBSC **105** includes a transcoder **106**, and a selection distribution unit **111**. System **100** preferably includes a plurality of mobile stations and base transceiver stations, but only one mobile station and two base transceiver stations are depicted in **FIG. 1** for clarity. In a preferred embodiment, system **100** is a Code Division Multiple Access (CDMA) system. System **100** may also be any communication system that transmits signaling messages and requires accurate delivery and receipt by mobile stations.

First base station **104** includes a transceiver **108** that includes a transmitter and a receiver. Second base station **103** includes a transceiver **107** that includes a transmitter and a receiver. Transceivers **107** and **108** transmit, over-the-air, RF signals to be received by mobile unit **102**. The transmission is well known in the art, and will not be described further in this application. Signals transmitted from base stations **103** and **104** to mobile unit **102** are referred to herein as forward traffic frames, or as forward link messages. Transceivers **107** and **108** receive messages from mobile unit **102**, as is well known in the art. Such messages are referred to herein as reverse link messages.

Mobile unit **102** is preferably a cellular telephone unit that is capable of communicating with base transceiver stations **103** and **104**. In a preferred embodiment, mobile unit **102** is a digital cellular CDMA telephone. Mobile unit **102** may also be a wireless data terminal or a videophone. Mobile unit **102** includes a transceiver **110** that includes a transmitter and a receiver, as is well known in the art. Mobile unit **102** communicates with base stations **103** and **104** by transmitting messages by the transceiver **110** located therein on a reverse link, and by receiving messages generated by base stations **103** and **104** at transceiver **110** located therein on the forward link.

In the preferred embodiment of the present invention, BTSs **103** and **104** act as the central location for managing power control in system **100**. In an alternate embodiment of the present invention, CBSC **105** manages power control in system **100**.

FIG. 2 illustrates a block diagram of a communication system layer structure **200** in accordance with the method and system of the present invention. In the preferred embodiment, **FIG. 2** illustrates a block diagram of IS-95 and cdma2000 layer structure. However, it will be appreciated by those skilled in the art that other communication systems, such as CDMAOne, UMTS, and ARIB, have similar layer structures. As shown in **FIG. 2**, IS-95 has a layered structure providing voice, packet data, simple circuit data, and simultaneous voice and packet data services. It should be noted that the term " IS-95" includes any of the standards that are predecessors to cdma2000, i.e. IS-95-A, and TIA/EIA-95-B. At the

most basic level, cdma2000 provides protocols and services that correspond to the bottom two layers of the ISO/OSI Reference Model (i.e., Layer 1 – the Physical Layer **202**, and Layer 2 – the Link Layer **204**) according to the general structure specified by the ITU for IMT-2000 systems. Layer 2 **204** is further subdivided into the Link Access Control (LAC) sublayer **206** and the Medium Access Control (MAC) sublayer **208**. In addition, a Quality of service (QOS) control mechanism **210** is included to balance the varying QOS requirements of multiple concurrent services. Applications and upper layer protocols corresponding to OSI Layers 3 through 7 utilize the services provided by the cdma2000 LAC services. Examples include signaling services, voice services, packet data applications(TCP/IP), and circuit data applications.

Sub B2

The design of the cdma2000 LAC and MAC sublayers **206, 208** is motivated by many factors, among those being: the need to support a wide range of upper layer services; the requirement to provide for high efficiency and low latency for data services operating over a wide performance range; support for advanced QOS delivery of circuit and packet data services; and the demand for advanced multi-media services that support multiple concurrent voice, packet data, and circuit data services, each with varying QOS requirements. The cdma2000 MAC sublayer **208** provides two important functions: (1) best effort delivery - reasonably reliable transmission over the radio link with a Radio Link Protocol (RLP) **212** that provides a best effort level of reliability; and (2) multiplexing and QOS control – enforcement of negotiated QOS levels by mediating conflicting requests from competing services and by the appropriate prioritization of access requests. The resolution of these conflicting requirements is handed to a scheduler that prioritizes the prepares the users and system requirements.

Sub B3

In the preferred embodiment, the Mobile Unit transmits channel quality feedback on the Reverse Link, which indicates the measured quality metrics of the forward link. These metrics can be explicit (actual values of channel signal to noise measurements such as C/I), implicit (power control commands) or a mixture of both. The channel quality metrics a fed into the scheduler which prepares the different transmission to the plurality of users and indicates the event to the MAC **208.** For these

Sub B3

applications, portions of the MAC are moved to the Base Stations from the PDG and CBSC 105.

Placing the decision making on the Base Station side of the link, allows for more intelligent scheduling with low latency and fast turn around decision based on the link statistics.

FIG 3. The power control command behavior given rayleigh faded channel at 3kph with 800Hz feedback.

FIG 4. Scheduling based on C/I measurements provided by each remote unit A and B. In the preferred embodiment of the present invention the scheduling may be for a common channel (such as a pilot channel) shared by a plurality of mobile units. The remote unit reporting the strongest C/I is scheduled first, where the actual modulation (QPSK, 16QAM, 64QAM) and the encoding rate used (½ or ¾) is determined by the strength of the C/I and other metrics available at the basestation indicating the available bandwidth for each remote unit. If enough bandwidth is available and the remote unit' s C/I are strong enough then both can be scheduled for the same time interval using separate orthogonal codes.

FIG 5. Shows that the forward dedicated control channel (DCH) voltage gain levels of remote unit A and B can be used to determine scheduling priority on the common channel due to the high correlation of the gain with the reported C/I measurements (see Figure 5). Scheduling the remote unit with the lowest DCH voltage gain is similar to scheduling based on C/I measurements passed from the remote units.

FIG 6. Shows that the accumulation of power control commands (also called the closed loop gain adjustment (CGA)) of the forward dedicated control channel (DCH) of remote unit A and B can be used to determine scheduling priority on the common channel due to the high correlation of the CGA level with the reported C/I measurements (see Figure 5).). Scheduling the remote unit with the lowest CGA is similar to scheduling based on C/I measurements passed from the remote units.

FIG 7. illustrates the different link fading parameters which in accordance with the method and system of the present invention. The scheduler uses these parameter to define its internal processing. For example, the Doppler rate 507 is used to define the fading mode (slow, medium, fast) which is used in the scheduling process and the channel coherence period 503 is used to determine the scheduling window for a given Mobile Station. It is noted that the actual channel gain during a constructive fade 504 is higher than the static channel reference point 505 by about 3-6db. As a result, scheduling a transmission only during the constructive fade will provide a net gain during this packet.

FIG. 8 illustrates the input to the scheduler from three different Mobile Stations 601,602 and 603; each subject to a different fade condition. The scheduler realizes that user one is in constructive fade at the beginning of the coherence time, and assigns the highest priority to packets directed to this user during the time slot 604. For time slot 605, the scheduler gives the highest priority to user three. During timeslot 606, the scheduler did not realize yet that user three is in a constructive fade, so the priority is assigned to user two, however the scheduler realizes that user two is well into the coherence period, and a fade is likely to happen within the 606 time slot. As a result the user two is assigned a lower transmission rate during 606 to allow for the higher possibility of a fade in this time slot. During time slot 607, the scheduler assigns the channel again to user two, but this time at full rate as no fade is expected. During time slot 608, the channel is assigned to user one.

Sub B4

FIG. 9 illustrates a flow chart detailing how the channel data is processed accordance with the method and system of the present invention. In the metric calculation module 701, the probability of the channel being in a constructive fade is scaled by a programmable parameter 'A' and combined with a priority Metric scaled by a programmable parameter 'B'. The Priority metric is a result of the time a packet is waiting in the transmission Que. The longer the wait time, the higher the priority for a given packet to be selected regardless of the channel conditions. Following the metric generation 701, the scheduler selects the highest metric in the metric selector 702. One the packet to be transmitted, or Mobile station to be serviced is known, the rate determination 703 defines which rate to use based on the channel

Sub B4

conditions 705 and the coherence time left in the fade cycle 706. The packet is transmitted in block 706. Block 707 resets the priority counters and the scheduling sequence starts all over again.

The foregoing description of a preferred embodiment of the invention has been presented for the purpose of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment was chosen and described to provide the best illustration of the principles of the invention and its practical application, and to enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.